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Ideal Bomber pt 39.

Cab 63/95

- Most Secret -   (Dept. OA)

25th September, 1939.

Dear Hankey,

I undertook the other day to let you have a copy of a papers written in the Air Ministry on "The Ideal Bomber." I send you one herewith. You will see that it was written in March 1938; this does not, of course, mean that its arguments do not apply today.

Yours ——

Cherwell

The Right Hon. Lord Hankey, G.C.B., G.C.M.G., G.C.V.O.,
Treasury Chambers,
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B.C. 18.

SECRET.

CONSIDERATIONS AFFECTING THE DESIGN OF THE IDEAL BOMBER AIRCRAFT FOR THE ROYAL AIR FORCE.

INTRODUCTION.

1. The terms of reference for this paper are limited to the consideration of the optimum size of bomber aircraft for the Metropolitan Air Force. The question of the size and type of bomber most suitable for the equipment of the bulk of the R.A.F. in the future is, however, of such fundamental importance, that in considering it we should not neglect the long view. The overriding consideration to-day is that our bombers must be suitable, as regards their radius of action, performance, bomb-load, etc., for their primary role - against Germany. But we cannot say who in five years' time will be our most probable enemy; it may be Russia, or Japan, or Italy, and therefore, as far as possible, our bombers must also be suited to strategical moves, and to operation from less highly organised bases than those which are likely to be available in this country.

2. The ideal is that we should be able to reinforce any part of the R.A.F. by air from any other part, not only overseas from home but vice versa. Experience has shown the very serious administrative disadvantages of a multiplicity of types of aircraft and engines when large reinforcement schemes have to be put into operation. This was particularly noticeable during the Middle East crisis of 1935.

3. We must also aim at ease and rapidity and economy in production, and ease and economy in training of personnel. This, again, can best be achieved by a reduction of the numbers of types in use, and by standardization of equipment.

4. Disregarding the Fleet Air Arm and Flying Boat we must have at least three basic operational classes - the bomber class in which will be included bomber-transport aircraft; the fighter class, including both fixed and moveable gun fighters; and the general purpose class, which includes army co-operation, general reconnaissance*, and the present general purpose overseas type.

5. It may be necessary to have more than one type in each class, and conversely one type may serve more than one class, but the ideal to set before us, subject to these three essential classes, is to reduce the number of types to the absolute minimum - bearing in mind that, actually in service in squadrons for a great part of the time, we are bound to have at least two types in each class, i.e. the obsolescent type and the replacement type.

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* G.R. aircraft are not included in the bomber class because the primary requirement in this sphere is numbers, not bomb-load. So G.R. aircraft should be kept as small (i.e. cheap) as possible consistent with the essential requirements of range, navigational facilities, etc. Incidentally they will always have some bombing capacity which, since they must have a fairly long range, would, when required, be a valuable addition to our striking force.

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It will therefore be the aim of this paper to suggest, if possible, one type of bomber with which all bomber squadrons, at home and overseas, should be equipped.

6. We now come to the second basic question of principle - that the bomber aeroplane should be of the optimum size both from the point of view of operations and administration.

Before we can consider this question we must postulate a minimum bomb load and radius of action.

It is considered that 1,000 lbs. is the minimum bomb load which can be regarded as economical, and that the bomber should have an operational radius of action sufficient to enable it to reach objectives in Eastern Germany. This would be 750 m., which requires a range in still air of 2,000 miles.

An aeroplane which can carry 1,000 lbs. of bombs for 2,000 m. in still air will be able to fly 2,700 m. without bomb load, i.e. an operational range which would allow it to fly non-stop to Egypt across France, or non-stop to Malta via Gibraltar. This point will be referred later, when the question of reinforcement of overseas commands is considered. (Paras. 57 and 58).

7. For the purpose of this paper, therefore, the lower limit will be assumed to be an aircraft with a range in still air of 2,000 miles and a bomb-load of 1,000 lbs., and a reinforcing range in still air without bombs, but with a disposable load of 500 lbs., of 2,700 miles. This type will be referred to as Type 'A'. As we must confine our examination within reasonable bounds the upper possible limit will be assumed to be an aircraft with six engines and a span of 180 feet. There is no chance of getting anything bigger than this within the next six or seven years.

In the table at Appendix 'A' is shown a comparison of five sizes of bomber aircraft, taking Type 'A' as the smallest size and the aircraft of 250 ft. span as the upper limit.

8. It should be clear that within these limits we are only considering the bomber class; it may be that for certain specialised purposes, such as dive-bombing or torpedo attack against ships, we shall require a type which does not fall within these two limits. But this type must be relegated to the general purpose class, and it is probable that it will serve other purposes within that class - such as the duties of air control in such places as Aden.

9. Another important point is that of finance. It is useless contemplating any air force which is going to cost more - capital and recurrent - than Scheme H, say in round figures £100 million a year. The capital cost of the initial equipment of the Bomber Force has been assumed, purely for the purpose of argument, to be £20 million. The number of aircraft that can be obtained for this sum varies inversely with the size, but the true criterion of cost of a bomber force is not, however, measured by the capital cost of the bomber fleet, but by the cost per ton of bombs delivered at the target in the face of enemy opposition.

10. Before going any further, it is necessary to set out in general terms the characteristics required of the type of aeroplane which would be best suited for employment in the main bombing offensive.

CHARACTERISTICS OF THE IDEAL BOMBER.

11. The characteristics of the 'ideal' bomber must be considered under two main requirements:-

First, the operational requirement - the primary one.

Secondly, the administrative requirement - including manufacture and maintenance.

These two are closely connected, and the second, although a subsidiary requirement, must, to a very considerable extent, affect the first.

The operational requirement.

12. The operational requirement must be considered under two heads, first the suitability of the aircraft in the air, and secondly on the ground.

Minimum size.

13. It has already been shown that the aircraft must have an operational radius of action to enable it to reach objectives in Eastern Germany, i.e. 750 miles. It must have the speed to enable it to take advantage of that range. In order to get the speed in an aircraft capable of carrying a 1,000 lb. bomb load with this radius of action it will be found that an aircraft of 18,000 lbs. all up weight,* or considerably larger than the Blenheim, is necessary.

Bombing and navigational facilities.

14. The ideal bomber should have the best possible facilities to enable it to reach the target under all weather conditions and to hit it when it gets there. This means that it must have the best possible facilities for the pilot, navigator and bomb aimer, good inter-communication, and should be capable of being rapidly and easily bombed-up on the ground. It must also be a good steady bombing platform. None of these factors will be affected adversely by an increase in size, and in many respects the large aircraft would be better. The navigational facilities in large aircraft will obviously be better - the bigger the aeroplane the more room there will be for navigator's compartment, chart tables, D/F wireless and so on.

Bomb Loads.

15. The object of this section is to consider the factors governing the bomb load of the ideal bomber. Before going on to consider this problem, it is worth re-iterating that:-

(i) There are five alternative types that we might build.

(ii) There would be overwhelming advantages in having our whole Metropolitan bomber force (and Commands abroad if possible) armed with one type.

16. The most difficult target that aircraft will be required to hit will be a ship, because the target is small, well defended

* See Type 'A', Appendix 'A'.

may offer itself for a limited time, and material damage, sufficient to sink the ship, must be caused. The proportion of the total bombing effort that will be expended against ships in a Home Defence war is likely to be very small; on the other hand an enemy Fleet might be an extremely important target, against which the bulk of our bomber force would have to be concentrated for a limited time; moreover it would be unsound not only strategically, but also from an administrative and supply point of view, to have only a small proportion of our bomber force specially designed and equipped to operate against ships.

17. The type of bomb required to destroy the most heavily protected type of ship - the capital ship - is:-

(i) Under way, 8 bombs weighing 250 lbs. each.

(ii) Stationary, the 2,000 lb. A.P. bomb.

So we may conclude that the minimum bomb load required if all bombers are to be able to attack capital ships, is therefore 2,000 lbs.; this can be carried either as one 2,000 lb. A.P. bomb, or as 8 - 250 lb. B. bombs.

18. The following methods of attack may be used against ships:-

(i) Dive-bombing. This is probably the most effective way at present, but it is more than doubtful if steep dive bombing, which has given such accurate results, will be possible with high performance modern types of a size to carry 2,000 lbs. of bombs. It is, however, probable that modern types will be able to carry out a modified form of dive bombing. The angle of dive will be less steep, probably about 20°, and the height of release will be higher, with resultant loss of accuracy, but trials already carried out, by Blenheim, Battle, and Wellesley Squadrons have shown quite promising results. It is also probable that spoilers, such as the leading-edge flap now being developed by the Bristol Aeroplane Co., may make it possible for modern aircraft to dive at steeper angles.

(ii) High Altitude (level) bombing - (For use against ships at anchor in a strongly defended base) - To obtain the best chance of hitting, a stick of bombs is employed, attacking the ship from the beam. Each bomb of the stick must be big enough to do its job, i.e. 2,000 lbs. In war conditions, against opposition, 10% of hits is an optimistic estimate - even this involved a bomb load of at least 20,000 lbs. if we are to get a reasonable chance of hitting from a single aeroplane.

(iii) Low Level bombing at high speeds across the bows of ships at sea, with B Bombs is probably the most effective method, but it is optimistic to expect in war more than 12% of hits, i.e. 1 hit out of the 8 B bombs that can be carried in the 2,000 lbs. bomb load.

(iv) Torpedo. Owing to increased protection of ships by bulges and increased A.A. armament of Fleets torpedo attack is nowadays a moribund method. If a limited number of torpedo bombers are considered necessary for coast defence work, they should be the same type

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as the F.A.A. torpedo-plane - in any case a limited number only will be required, and this requirement should not affect the basic design of the Bomber class.

19. For the attack of ships, therefore, a bomb load of at least 2,000 lbs. is required, while a load of 20,000 lbs. would not be too much.

20. To turn now to the attack of targets other than ships, it is clear from A.S.M.56 that both the 500 lb. and 250 lb. bombs are essential - of the 16 most important targets listed, 11 are suitable for both types, 4 require 250 lb. and 1 requires 500 lb. So obviously the Ideal bomber must be able to carry a reasonable number of 500 lb. bombs, with an alternative load of as many as possible 250 pounders.

21. We have seen that it is desirable that all bombers should be able to carry at least 2,000 lbs. of bombs for the purpose of attacking ships, and all bombers should, therefore, be designed (possibly with some minor modification so that a proportion are always available, while the rest could be rapidly converted) to take the 2,000 lb. A.P. bomb. It is worth inquiring whether it is likely to be operationally economical to carry less than four 500 lb. bombs or eight 250 lb. bombs in one sortie for any purpose.

22. This can be answered in fairly general terms:-

(i) The minimum effect to be aimed at, (purely from a bombing point of view), is that each bomber should be able to carry as many bombs as will give him a reasonable chance of getting at least one hit <u>under war conditions</u>. If we assume that the chance of hitting will be 10%, and it is certainly not likely to be more than that, ten bombs will be required, i.e. 10 x 250 = 2,500 lbs. or 10 x 500 = 5,000 lbs.

(ii) Apart from this, there is the question of the "proportion of effort" (excluding risk of loss which is considered elsewhere) required to get a given bomb load to the target. The type 'A' carries 1,000 lbs., if the <u>same aircraft</u> could carry 2,000 lbs., with the same crew, it could deliver twice the weight of bombs at the target - or at more than one target - with the same effort, same amount of time spent over enemy territory, same work required by crew and ground personnel, same expenditure of fuel, etc. As aircraft get bigger and as ranges increase, the crew, the size and number of the engines, the fuel expenditure, the number of ground personnel required, etc. increase, but not in proportion to the bomb lift - so from this aspect, with a minimum essential radius of action of 750 miles, which requires two pilots whatever the size of the aeroplane, operational economy increases rapidly with size.

(iii) It is sometimes argued that 2,500 lbs. would be too much in many cases - i.e. that there are targets which do not require as much as 10 x 250 lb. bombs or 5 x 500 lb. bombs. This may be true, but the point is that at least ten 250 lb. bombs are required in order to ensure one hit under war conditions, and there must

be very few targets for which one hit with a 250 lb. bomb is too much.

(iv) Is there any object operationally in going bigger still? Are there any targets which require more than 2,500 lbs.? Certainly for capital ships, while for other targets the principle of economy of effort would justify a good deal more, cf. one sortie may attack two different objectives en route to its main objective, and two more on the way back, say five different targets in one sortie - in other words, one large aeroplane might be the equivalent either of a formation of smaller ones attacking the same target, or a number of single smaller ones attacking different targets.

23. A glance at column 12 of Appendix 'A' will show that the total bomb lift obtainable for a capital cost of £20,000,000 increases with the size of the individual bomber. The most important increase, however, occurs between Types 'A' and 'B'; and the increase between Types 'B' and 'E' is small compared with the large reduction of numbers of aircraft.

24. The conclusion under this head is that the smallest load worth considering is 2,000 lb. while from the bombing point of view there are advantages in having aircraft with a normal load of anything up to 20,000 lb. There seems to be no reason for having a mixed force consisting of bombers with differing load carrying capacities.

Control.

25. It is far easier to control 683 aircraft of Type 'B' than 1380 aircraft of Type 'A'. Apart from the obvious ease of despatching individual aircraft instead of formations, the control of returning aircraft in bad weather would be much simpler. One of the great difficulties of operating a bomber force will be control in bad weather, and under these conditions, congestion in the air should be, as far as possible, avoided. A reduction in numbers will do much to assist in the solution of this problem. There will be, including Scheme H, 42 bomber stations in existence which, with Type 'A', would mean an average of 34 aircraft per station. With 'B', the number could be reduced to an average of 17 per station.

PROTECTION.

26. The 'ideal' bomber must be capable of evading or dealing adequately with opposition on its way to and from the objective.

It has been suggested that it is possible for the bomber to rely for its protection entirely upon evasion. It is, of course, true that the aeroplane has no means of protection against A.A. fire except evasion, and it is argued that, by eliminating defensive armaments, the speed of the bomber can be so much increased that it can afford to rely upon evasion in order to protect it from the fighter also.

27. It can, however, be urged against the adoption of such

a policy that:-

(i) The unarmed bomber cannot rely upon being faster than the contemporary fighter. Even if it could approach this condition when it was first produced, it would very rapidly become obsolescent. It would therefore require replacement at very frequent intervals:

(ii) The possession by the bomber of defensive armament will tend to make the fighter keep his distance, and will mean, in practice, that a proportion of bombers attacked by fighters will not be destroyed. If, however, the fighter knows that the bomber has no armament, he has nothing to fear and can close in to point blank range and make certain of a kill.

28. The relatively high speed of the unarmed bomber might give it a reasonable chance of avoiding interception by fighters under conditions of darkness or bad visibility, but in clear weather it is hard to believe that such bombers would be able to penetrate far in the face of a modern system of fighter defence. While there might be something to be said, therefore, for building the unarmed bomber for use at night or in thick or cloudy weather, it is quite obvious that for general use an unarmed bomber could not be accepted. In the interests, therefore, of the all-important principle of reducing the number of types to the absolute minimum, we recommend that the inclusion of any unarmed bombers in the force should not be considered.

29. Thus the ideal bomber must have:-

(i) Defensive armament and, possibly, protection (i.e. armour).

(ii) Capacity for evading anti-aircraft fire.

Defensive Armament.

30. If one type of bomber, therefore, be adopted for general use it must be equipped with defensive armament. This armament should be capable of developing a volume of fire sufficient to engage the maximum number of fighters which can attack simultaneously and the fields of fire of the guns should allow of the smallest blind area possible.

31. At the present time the Air Forces of all countries rely primarily upon fixed gun fighters for the attack of bombers. Experimental work at A. and A.E.E. and at A.F.D.E., (and also practical experience in the Spanish war) has shown that the modern high performance fixed gun fighter can only operate successfully in the astern attack. The defensive armament for the bomber has consequently been arranged primarily with a view to dealing with this form of attack. This has led to the adoption of power-operated turrets mounted in the tail to carry four guns. These turrets have approximately a traverse of 180°, an elevation of 60° and a depression of 45°.

32. Power operation for these turrets is essential as it has been found impossible to use manual operation at speeds in excess of 200 miles an hour. The power-operated four-gun turret equipped with 1,000 rounds per gun is a bulky object of an unstreamlined shape and its weight is approximately 1,000 lbs. It is an impossibility to place such a turret in the tail of a

bomber of the size of type 'A'. The only type of power-operated turret which can be mounted in this aeroplane is a two-gun turret in the amidship position. The volume of fire available from such a turret is only half that of a four-gun turret and its field of fire astern is limited by the obstructions caused by the fin, rudder, and tail plane. Its field of fire downwards is almost negligible.

33. In the type 'B' and larger bombers it is possible to provide a four-gun tail turret without serious interference with the structural design or the aerodynamic qualities of the aeroplane. In these large aeroplanes the fuselage structure near the tail must necessarily be of a certain size in order to take the loads, and it is not possible to taper the fuselage down to a fine point. Consequently the fitting of a powerful tail turret does not detract appreciably from the performance, and the larger the aeroplane the less is the relative reduction in performance.

34. The size of the type 'A' bomber does not allow of the fitting of a power-operated turret in the nose. Forward defence must be provided either by fixed guns or by manually operated guns having very restricted fields of fire. Such forms of armament are extremely inefficient when compared with the power operated two-gun turret which can be fitted to the type 'B' and larger bombers. The combination of power-operated nose and tail turret gives the type 'B' bomber an excellent field of fire with only a small blind area above and below. Any fighter aiming to attack in this blind area is likely to have to pass through the fields of fire covered by the nose and tail turrets. As opposed to this powerful and effective system of defensive armament the type 'A' bomber can at best be provided with a two-gun amidships power operated turret, plus an extremely inefficient, limited system of forward defence. The fire power of the type 'A' bomber is, therefore, small and its blind areas are large.

35. Air Forces of all Powers are now turning their attention towards the turreted fighter and to guard against attack from such fighters it is desirable to provide some form of downward defence. The retractable "dustbin" turret has been designed to combat such a form of attack. This form of turret cannot be streamlined and, when extended, causes an appreciable loss in performance; but on the other hand, it reduces the blind area below the bomber to practically nothing, and in addition enables the bomber to re-inforce the fire power of either nose or tail turret with two additional guns. The type 'A' bomber is too small to allow of the fitting of this form of turret, but it can be fitted in the type 'B' and larger bombers, and in aeroplanes of this size the turret represents a comparatively small proportion of the total drag. New desighs of dragless turrets for downward defence are being developed but all such turrets must be of a size and weight which precludes their being fitted to the type 'A' bomber, which consequently is extremely vulnerable to attack from turreted fighters.

36. Although the great majority of military aeroplanes of all countries at the present time are equipped with machine guns firing a bullet of .5 or less calibre, increasing attention is being paid to the development of larger weapons capable of firing explosive shells. If such weapons should be adopted the target would then become the entire aeroplane structure instead of the crew, engines and tanks, which represent the target of machine gun fire. The target area available for the large calibre weapon may

be anything up to, or even over, twelve times the area of the target presented to the machine gun, as such weapons will probably shoot at the plan view of the aeroplane.

37. The advent of large calibre weapons firing explosive shells will make the problem of downward defence even more important than it is at present. If it be decided to standardise one type of bomber over a period of years this type must be capable of meeting attack from such weapons. In aeroplanes of the size of type 'B' and larger it will be possible to mount large calibre weapons in the nose and tail and amidships. There is also a possibility that the large aeroplane may have wings thick enough to accommodate turrets in the wing, which would make possible a considerable increase in the defensive power.

Formation flying.

38. The defensive armament of bombers is intimately connected with the question of formation flying. Advocates of the small type 'A' bomber claim that the fire power of a sub-formation of five of these bombers is approximately equal to that of one larger bomber fitted with modern nose, tail and amidships turrets. On the other hand the single large bomber represents a far smaller target than the sub-formation and it cannot be attacked by so many fighters at once. Nor can a fighter shoot at two or more bombers in line.

39. The very limited armament of the type 'A' bomber compels such aeroplanes to operate in formation, whereas types 'B' to 'E' are capable of defending themselves when operating individually. The advantages of being able to do so are very considerable, and may be enumerated as follows:-

(i) If aircraft are capable of operating individually instead of in formation, it will increase the number of "missions" that can be sent out, and this will automatically increase the number of interceptions that enemy fighters will have to make. This will, on the average, reduce either the number of fighters that can engage one bomber, or the number of the bombers that can be engaged.

(ii) An aircraft can operate individually in conditions of weather and visibility which would make formation flying impossible, or at best possible only for very experienced and highly trained pilots.

(iii) The necessity of flying in formation naturally reduces both the cruising speed and range of a given aeroplane.

(iv) A formation of small aircraft is more easily detected and held in view by defending aircraft and guns, than a single larger aeroplane capable of carrying the same weight of bombs.

(v) A single aircraft can make the maximum use of clouds for concealment and evasion.

(vi) The abolition of formation flying from the training syllabus, would allow more time to be given to navigation, bomb aiming and the study of tactics.

40. The ability to operate individually has also a

considerable bearing on the question of protection from A.A. fire. The Manual of Air Tactics, dealing with anti-aircraft fire, makes it clear that:-

(i) A round fired at the leading aircraft of a formation at say 10,000 feet has a fair chance of hitting another aircraft if it is flying within 50 yards to the flank and within 100 yards behind.

(ii) Aircraft in formation are better targets for anti-aircraft guns if they are so close together that an effective round for one aircraft is also effective for another.

41. Aircraft should therefore be separated in formation by a distance in plan of at least 100 yards, and as this is too far for adequate supporting fire, it follows that the formation must be capable of rapidly "opening out" to cope with A.A. fire, and of equally rapidly "closing in" to deal with fighter attack. Apart from the fact that this implies a high standard of air drill which may be difficult to obtain with war-trained pilots, it is by no means improbable that the increased ranges now contemplated in air fighting may make it possible for a bomber to be subjected to A.A. fire and fighter attack simultaneously. The ideal sub-formation is therefore a single aircraft which is fully capable of protecting itself, and which will be able to evade anti-aircraft fire by manoeuvre far more easily than a sub-formation of smaller aeroplanes.

42. The single large aeroplane will have a much smaller total vulnerable area than the sub-formation of smaller aircraft and if anti-aircraft salvo misses it, no harm is done and there are no other aircraft close by to be hit. On the other hand, there is the disadvantage that one hit by an A.A. shell may destroy the single large aeroplane, though it is unlikely to destroy more than one or two of a formation of smaller aeroplanes.

43. The conclusions under the sub-heading "Defensive Armament" may be summarised as follows:-

(i) Owing to the small size of type 'A' it is impossible to provide any armament other than a two-gun power operated turret amidships and very limited forward armament.

(ii) The type 'A' cannot be adapted to meet attack from turreted fighters.

(iii) The type 'A' cannot be adapted to meet attack from large calibre weapons firing explosive shells.

(iv) These limitations mean that this type of aeroplane must be operated in formation and it is therefore more vulnerable to anti-aircraft fire and fighter attack than is an individual aeroplane.

(v) The type 'B' and larger bombers have the following advantages:-

(a) They can be fitted with a powerful and efficient four-gun turret in the tail.

(b) They can be fitted with a two-gun power operated turret in the nose.

(c) Provision can be made for power operated turrets amidships to meet attack from below.

(d) The aeroplanes are of a size which enables them to carry, if necessary, large calibre weapons.

(e) Their armament is powerful enough to enable them to operate individually, which not only renders them less vulnerable than formations to both fighter and anti-aircraft attack, but also has many operational advantages.

(f) The large aircraft will be less liable to be put out of action by machine-gun or even cannon fire, because the main load-carrying structure, being larger, is more able to resist damage by bullets or small shells. On the other hand, by increasing the size and therefore the relative importance of the bomber, it becomes more worth destroying, and action such as ramming begins to come into the practical picture.

44. It is, of course, true that an aircraft, for instance, of Type 'C', is a larger target than one aircraft of the Type 'A', but, although it will carry from 4 to 12 times the weight of bombs, its span will only be 96/100 ft., as against 58/60, an increase of only 60%. It may also be slightly less manoeuvrable than the smaller aircraft, but high manoeuvrability is not an important requirement in a bomber, and it is certainly much more manoeuvrable than a sub-formation of smaller aircraft capable of carrying the same bomb load.

Armour.

45. Up to the present time very little work has been done in the way of providing armour for bombing aircraft. With the advent of larger bombing aeroplanes, having a large disposable load, armour plate may be worth consideration.

To be of any use against even .303 Armour Piercing bullets, the weight of armour must be very considerable, for an armour plate box proof against the .303 A.P. at 200 yards, capable only of accommodating the pilot, would weigh approximately 1,200 lbs. This effectively puts it out of court for smaller aircraft. It would, for instance, more than absorb the entire bomb-carrying capacity of type 'A'. On the other hand, if the full bomb load were 12,000 lbs. (type 'C') it might be well worth sacrificing 20% - say 2,500 lbs. of bomb load for that weight of armour, if by so doing you could increase the chances of the aircraft reaching the target and getting back again by more than that percentage. Moreover the moral effect of a certain amount of armour would be very valuable.

46. It might be possible to have a small armoured control cabin forward and an armoured bulk-head aft to give some protection to the crew (from the point of view of morale it would be undesirable to give armour to the pilot and none to the crew). It is obviously not possible to armour all the tanks, but

arrangements for sub-dividing the petrol into a number of subsidiary tanks with adequate jettison facilities is worth examining, providing its disadvantages in the shape of extra complications do not outweigh the possible advantages.

47. It appears, therefore, that it is practicable to provide bombers of Type 'B' and larger with armour against the .303 bullet. If enemy fighters use larger calibre weapons, however, it will be quite impossible to provide adequate armour in any aeroplane within the upper limit of size, especially if a proportion of A.P. ammunition is used by the enemy fighters.

Speed.

48. Although, we have seen, it would not be sound policy to rely on speed for protection to the point of abolishing defensive armaments, the ability to fly at high speed has the following advantages.:-

(i) It reduces the margin of speed possessed by the fighters and, as a consequence, increases the difficulty of interception.

(ii) It reduces the time spent over the enemy's territory, and therefore the time spent in a defended area, for a given depth of penetration.

(iii) It increases the difficulties of the A.A. gunner, since the aeroplane, at a given height, travels further during the period of calculation and the time of flight of the shell.

49. A glance at Appendix 'A' will show that speed tends to increase with size until an all-up weight of 80,000 lb. is reached. From the point of view of speed therefore, increase of size is an advantage. It is worth noting, in this connection, that the giant type 'E' is substantially faster than the small type 'A'.

50. The general conclusion, therefore, under the sub-heading of "Protection" seems to be that in the air the balance is strongly in favour of the aeroplane of Types 'B' and 'C', and that the chances of its loss, either from enemy fighters or from A.A. fire, are much less than in the case of the smaller aeroplane of Type 'A'. With an increase of size to Types 'D' and 'E' the advantage is not maintained, as there is an increase in geometrical size without any considerable increase in fire power or speed. Type 'D' is slightly faster than Types 'B' and 'C', but Type 'E' has the same speed as Type 'C'.

Effect of losses.

51. Column 10 of Appendix 'A' shows that for a capital expenditure of £20,000,000 we can have:-

1,380 Type 'A'

683 Type 'B'

490 Type 'C'

323 Type 'D'

166 Type 'E'

An aeroplane of whatever size is still a fragile thing, in the sense that it is easily destroyed, and it is obvious that one hit with an A.A. shell or a crash (even a bungled forced landing) might destroy an aircraft of any type equally effectively. It has been said, therefore, that it is not sound to put "too many eggs in one basket". Each individual aircraft would tend to become too precious - there would probably arise the same tendency to avoid risking it that was noticeable in the last war in respect of large warships.

52. The problem, however, is really one of the ratio between the vulnerability and ease of replacement of the various types. On the basis of cost and industrial effort, it would be rather easier to produce Type 'E' (total bomb lift 44,000 lbs.) than 8 Type 'A' (total bomb lift 8,000 lbs.). The question is whether we are more or less likely to lose one Type 'E' than 8 Type 'A'. It is not possible to assess with accuracy the relative vulnerability of each type, but it is worth noting that if we assume a flat rate of wastage for all types, we find that we should lose 8.4 Type 'A' for one Type 'E'.

53. On the same assumption we should lose 2 Type 'A' for one Type 'B' but we should, also, on a basis of cost and industrial effort, be able to replace one Type 'B' (total bomb lift 8,000 lbs.) as easily as two Type 'A' (total bomb lift 2,000 lb.). From the arguments in paras. 26 - 47 it appears that we might well lose more than two Type 'A' for one Type 'B'.

54. In many ways the larger types show an advantage. In the matter of equipment, for instance, the loss of one bomber, of whatever size, means the loss of one automatic pilot, one bomb sight and so forth. From the point of view of personnel the large aircraft also has the advantage, for the loss of one Type 'E' would involve 2 pilots and 6 crew, while the loss of eight Type 'A' would involve 16 pilots and 16 crew.

55. Broadly speaking, therefore, if the rate of wastage is the same for all types, there is little to choose from the point of view of ease of replacement, but the larger aircraft has some advantage in the matter of equipment, and a large advantage from the point of view of personnel.

56. Although it has been shown that Type 'B' is a good deal less vulnerable than Type 'A', it is probable that a further increase in size would not be accompanied by a proportionate reduction in vulnerability. It would for instance be worth ramming the larger sizes. Type 'B', or possibly Type 'C', is probably therefore the best compromise.

STRATEGIC MOBILITY.

57. The importance of strategic mobility was referred to in paragraphs 2 and 4 above, when it was pointed out that a range of 2700 miles without bomb load was required in order to enable a bomber to fly non-stop to Egypt across France, or non-stop to Malta via Gibraltar.

58. At Appendix 'C' is a table showing the loads that could be carried by the five types when carrying reinforcement flights with a range of 2750 miles. Type 'A' can carry 2250 lb. with the 1000 yds. take-off, but Type 'B' can carry three times as much -

6650 lb. The advantage of being able to carry sufficient maintenance personnel and equipment to enable the unit to operate on arrival, and until the arrival of supplies through the normal lines of communication, has tended in the past to be under-rated, and cannot be too highly stressed.

OPERATIONAL REQUIREMENTS OF THE "IDEAL" BOMBER ON THE GROUND.

59. The aircraft must be able to operate with full load from aerodromes in this country and from as many as possible overseas. As all bomber aerodromes at home and principal aerodromes overseas will permit a take-off run of 1,100 yards, it is clear that we can regard the loads shown in column 4 of Appendix 'A' as practicable. The first point to note is that Type 'A' cannot take advantage of any increase of run over 700 yards as, in order to obtain the speed shown in column 5, it is necessary to keep the fuselage so small that no bombs in addition to the basic load of 1,000 lb. can be carried.

60. There is a limit to the weight per wheel which can be supported under all conditions by a natural grass-surfaced aerodrome, but provided that the tyre pressures are kept low (35 lb. per sq. in.) there is no more risk of damage to good grass surfaces than with smaller aeroplanes. If, however, it should be necessary greatly to exceed this pressure some form of prepared surface, such as concrete, must be adopted. Apart from the question of expense, which is considerable, concrete surfaces have two very serious disadvantages:-

(i) They increase the power of air attack to interrupt the operations of a bomber force, both because they are conspicuous from the air, and because they can be smashed by bombs.

(ii) They reduce the mobility of air forces both in the strategical and tactical sense, because aircraft carrying full loads will be forced to operate from a necessarily limited number of specially prepared and organised bases.

The optimum size of bomber should not therefore exceed that which can operate from natural grass surface.

61. From recent experiments, it appears that aircraft up to and including Type 'C' can be operated from normal aerodromes, although it is not yet quite certain that Types 'B' and 'C' will be able to take off with the full load shown in Column 4 of Appendix 'A'. Some reduction, which will probably not be large, may have to be accepted.

Vulnerability on the ground.

62. It is also necessary to consider the relative vulnerability of the large and small aircraft on the ground. The larger a bomber becomes, the more difficult is it to conceal and give protection to each individual aeroplane on the ground. On the other hand:-

(i) The increase in geometrical size is not proportionate to the increased bomb carrying capacity. For instance,

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an aircraft of Type 'A' would have an area of approximately 800 sq. ft. for a bomb lift of 1000 lbs., while Type 'B' would have an area of about 1400 sq. ft. for a bomb lift of 8000 lb.

(ii) Suppose the total bomber force should consist either of 683 Type 'B' or 1,380 Type 'A'* the former could be far more easily and cheaply dispersed on the ground, either by the same degree of dispersal on half the number of aerodromes, or by wider dispersal of the aircraft on the same number of aerodromes.

63. A bomber fleet equipped with Type 'A' would present an area of (1380 x 800 sq. ft.) approximately 368,000 square yards for a bomb lift of 616 tons, while if equipped with Type 'B' it would present an area of approximately (683 x 1400 sq. ft.) 318,750 square yards, for a bomb lift of 2434 tons. On the ground, therefore, the balance appears to be in favour of the large aircraft, mainly on account of the advantages in concealment and dispersal given by reduced numbers, which more than offsets the increase in geometrical size+.

Manning.

A. Flying Crews.

64. At Appendix 'B' is a table showing a comparison of the numbers of flying personnel required to man a bomber fleet equipped with the five types of aeroplane. For the purpose of this comparison it has been assumed that the numbers of aeroplanes specified in Column 10 of Appendix 'A' are initial equipment only. It will be seen from Column 11 of Appendix 'B' that the total number varies from 5520 with Type 'A' to 1328 with Type 'E'.

65. If, merely for the purpose of comparison, we assume a wastage of 33% of initial equipment per month in war, then the force will require the following numbers of pilots per month.

If equipped with Type 'A'	-	920
" " " " 'B'	-	455
" " " " 'C'	-	327
" " " " 'D'	-	215
" " " " 'E'	-	111

66. In order to give some idea of what such wastage involves, if we assume that the average output of an F.T.S. in war time is 20 pilots per month, then the bomber will absorb the output of the following number of F.T.S.'s.

If equipped with Type 'A'	-	46 schools.
" " " " 'B'	-	22 "
" " " " 'C'	-	16 "
" " " " 'D'	-	11 "
" " " " 'E'	-	6 "

* See Appendix 'A' Column 10.
+ See Appendix 'A' Column 6.

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67. It may be argued that the larger types of aircraft will require a more experienced type of pilot, who would be difficult to replace in time of war. The large bomber, however, which is fitted with an automatic pilot, and which does not require to fly in formation, will not demand a particularly high degree of piloting skill except for taking off and landing. There is nothing inherent in the design of the larger bomber which makes it more difficult to take off or land, and it is clear that if pilots need not be trained in formation flying they will have a great deal more time to devote to take-off and landing practice. There is also reason to hope that the design of wings and undercarriages may in the future be improved (leading edge flaps and the Douglas three-wheeled undercarriage are examples of what is meant), and the technique of the approach and landing made considerably easier.

68. Similarly, the force will require the following replacements per month of air observers and W/T operator air gunners:-

	Air Observers	W/T operator air gunners.
Type 'A'	690	690
" 'B'	342	683
" 'C'	245	735
" 'D'	162	646
" 'E'	83	332

Thus, while the numbers of air observers are, like those of pilots, directly proportional to the numbers of I.E. aircraft in the fleet, the numbers of W/T operator air gunners are approximately the same for Types 'A', 'B', and 'C'. This is due to the increase in the numbers of gun positions per aircraft, which counter-balances the reduction in the numbers of I.E. aircraft in the fleet.

69. There is therefore a progressive decrease in the total numbers of flying personnel required with increase in size, and the larger the aircraft the more economical it is from the point of view of flying personnel. It has been shown above that the wastage rate of Type 'B' is likely to be less than that of Type 'A', and Type 'B' would therefore show an even greater economy in personnel than appears in the above tables, calculated on a flat rate of 33% for all types.

70. It is also interesting to compare the weight of bombs which can be carried into the air per man of the flying crew, assuming a take off run of 1000 yds. over a 50 ft. screen in still air:-

Type.	Total Bomb lift.	Total crew.	Weight of Bombs per man.
A	1000 lb.	4	250 lb.
B	8000 lb.	5	1600 lb.
C	12000 lb.	6	2000 lb.
D	20000 lb.	7	2857 lb.
E	44000 lb.	8	5500 lb.

B. Maintenance personnel.

71. It has been assumed that the numbers of aircraft shown in column 10 of Appendix 'A' are initial equipment, and that Types 'A' to 'C' are organized in squadrons on a basis of 12 I.E. aircraft and Types 'D' and 'E' on a basis of 8.

On these assumptions the numbers would be as follows:*

Type 'A'	-	115 squadrons	17,940	officers, W.O's N.C.Os. and airmen.
" 'B'	-	57 "	9,120	"
" 'C'	-	41 "	8,241	"
" 'D'	-	40 "	5,560	"
" 'E'	-	21 "	4,389	"

72. The general conclusion under this heading is that economy in flying and maintenance personnel required for the bomber fleet increases with an increase in the size of the aircraft, but that the most remarkable increase in economy is between Types 'A' and 'B'. Type 'B' requires rather more than half the flying and maintenance personnel to man the bomber fleet that are required if Type 'A' is employed. Thereafter with increase in size of the aeroplane there is a small but steady increase in economy in man power.

73. A large reduction in the man power necessary to fly and maintain the bomber fleet would have an important bearing on the difficult problem of reserves. This would be particularly noticeable during the six or seven years immediately following the decision to re-equip the Air Force with the larger bomber. During this period the numbers in the reserve would be relatively much greater, and would cover wastage for a longer period.

Bomb reserves.

74. The increased carrying capacity of larger bombers would necessitate an increase in the bomb reserves. The following table gives an approximate idea of what such an increase would be:-

1	2	3
	Striking force equipped with type specified, but otherwise as in Scheme 'K'.	
	Type 'A'.	Type 'B'.
6 month reserve H.E.	77,350 tons.	243,960 tons.
" Incendiary	10,570 "	37,120 "
Capital cost	£16,000,000.	£50,000,000.
Annual storage	£880,000.	£2,811,000.

With an increase in the bomb reserve to the tonnage shown in col. 3 of the above table, simplification of bombs and

* Suggested establishments attached as Appendix 'D'.

above all, fuses, with a resultant decrease in cost, would become important.

Repair and maintenance.

75. The most rapid form of repair is by replacement of components strictly interchangeable, of transportable sizes and reasonably easy to handle. With aircraft of types 'A', 'B' and 'C' these essentials can be achieved. With larger aircraft, however, a number of difficulties arise. Major components must be sub-divided; sub-division leads to complication and involves a large increase in the work and time of replacement; interchangeability is difficult to achieve, and handling entails complicated and unwieldy equipment. In fact, with giant aircraft the replacement of major components is virtually impracticable, and economy of important spares by salvage cannot be achieved.

76. Small aircraft can be repaired under simple schemes not involving complicated tools or processes, which can therefore be applied by squadron or station personnel under almost any conditions. Very large aircraft, on the other hand, are not susceptible to simple repair schemes. They would have to be treated in much the same way as naval vessels. Each repair would have to be specially evolved and stressed, and could only be done by manufacture from materials.

77. Aircraft of greater size than Type 'C', therefore, would cause difficulties as regards repair and maintenance, and might necessitate a complete reorganisation of our existing system.

Manufacture.

78. From the point of view of manufacture the large bomber has certain advantages over the small bomber. These may be enumerated as follows:-

(i) The total number of accessories, i.e. bomb sights, automatic pilots etc. is reduced, since each aeroplane requires only one set of accessories.

(ii) The number of sets of jigs and tools for mass producing the large bomber will be less than in the case of the small bombers.

(iii) The rapid production of small aircraft is impeded by the impossibility, owing to restrictions of space, of employing a sufficient number of men on the work of installation. With increase of size this difficulty is proportionately reduced.

(iv) An increase of size reduces the floor space required in the factory, i.e. it requires less floor space to build 683 Type 'B' than 1380 Type 'A'

CONCLUSIONS.

79. From considerations of production, supply and maintenance, it is essential to reduce the number of bomber types in service, and if possible to standardize on one type. The type selected for mass production and general use must be of a size which will achieve the required result in the most economical way from the point of view of supply, maintenance and operational qualities.

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80. Range and bomb load are determined by considerations of economy and efficiency in operation, and by the general strategical situation in the world in so far as it can be foreseen for the period of time during which the aeroplane is likely to be in service. Taking a Continental war as the primary role, the minimum bomb load, from the point of view of economical operation, should be 1,000 lb. and the minimum range should be 2,000 miles with a reinforcing range of 2,700 miles.

81. Five types have been considered in this paper, ranging from Type 'A', with an all-up weight of 18,000 lbs., to Type 'E', with an all-up weight of 160,000 lbs.

The types which have been chosen are all either in process of design or have formed the subject of study by competent designers. The paper is therefore based as far as is possible on practical rather than on purely theoretical considerations.

82. The foregoing paragraphs have shown that, if the bomber aeroplane is considered solely as a vehicle for the carrying of bombs, an increase in size of the aircraft is accompanied by a general increase in efficiency i.e. the larger the aircraft the larger is the percentage of the all-up weight which can be devoted to the bomb load.

This is clearly shown in the following table:-

Type.	All-up Weight.	Bomb Load.	Bomb load as percentage of the all-up weight.
A	18,000 lbs.	1,000 lbs.	5.5%
B	35,000 lbs.	8,000 lbs.	23%
C	55,000 lbs.	12,000 lbs.	22%
D	80,000 lbs.	20,000 lbs.	25%
E	160,000 lbs.	44,000 lbs.	27%

The most remarkable increase in efficiency takes place between Type 'A' and Type 'B' and thereafter the increase is more gradual.

83. An increase in size is also accompanied by greater economy in the flying personnel required to carry a given weight of bombs, and in the personnel required to maintain the aircraft. The speed of the bomber increases up to an all-up weight of 80,000 lb. after which it begins to fall again. From this point of view, therefore, regarding the aeroplane as a transport vehicle, the optimum size would appear to be about 80,000 lb. It is, however, possible that with the geodetic system of construction, which is peculiarly suited to large aeroplanes of high aspect ratio, the optimum size might be 160,000 lbs. or even larger.

84. The bomber aeroplane cannot, however, be considered solely as a transport vehicle. Two very important additional characteristics are required - it must be capable of taking off from and alighting on natural surfaced aerodromes of reasonable size (1100 yds. diameter circle), and it must be capable of reaching its objective and returning home, which involves a

reasonable capacity for dealing with both A.A. guns (of all sorts) and defending fighters.

85. To deal first with the ability to take off from and land on normal aerodromes, there is no reason to suppose that aircraft up to and including Type 'C' will be unable to do so.

86. With regard to the power of defence, it is clear that there is some point at which increase in size is a disadvantage. It is easy to use the argument of "reductio ad absurdum". If an aeroplane could be built which could carry, say, 1000 tons of bombs, it is quite certain that we should lose it very soon, probably on the first day of war, because the enemy's defence could concentrate against it (it would be worth while ramming it), but if we had 1000 aeroplanes, each capable of carrying one ton, we should not lose more than a fraction in the same period. But the difficulty is, in practice, to determine the exact size at which the increased fire power of the bomber begins to be counter-balanced by the disadvantages of the reduced number that can be built for a given sum.

87. We can say at once, however, that Type 'A' is too small. It cannot carry power operated nose or tail turrets, nor can it be given a satisfactory downward defence. Its fire power is therefore so weak, and it has so many blind spots that it must fly in formation, and rely for its defence on the supporting fire of neighbouring aircraft. The disadvantages of this form of defence have been dealt with above.

88. The advantages in every way of Type 'B' over Type 'A' are very remarkable. The bomb lift of the fleet would be increased from 616 tons to 2,434 tons, the speed would be slightly increased, the defensive fire-power greatly improved and the numbers of flying and maintenance personnel would approximately be halved. The span of each bomber would be increased from 58/60 ft. to 80/84 ft., while the number of aircraft in the fleet would be reduced from 1380 to 683. It is sometimes argued that the possession of a large number of bombers is an advantage because it denies to the defenders the power of concentration e.g. that against a defending force of 400 fighters it would be better to have 1380 bombers than to have 683. There would be more force in this argument if the 1380 bombers could operate singly, but, as it is, these small bombers must fly in formation. Even if they fly in the smallest possible formation, i.e. three aircraft, it means that 400 fighters will have to deal with 460 missions, whereas if Type 'B' is employed, capable of operating individually, they would have to deal with 683 missions.

89. A further increase in size to Type 'C' does not show a comparable gain. The total bomb lift of the fleet is increased from 2434 tons to no more than 2620 tons, and the numbers of personnel required are only slightly reduced. there is also a further slight increase in speed. On the other hand the span is increased from 80/84 ft. to 96/100 ft. and the numbers reduced from 683 to 490. In addition, Type 'C' is not a substantial improvement on Type 'B' from the point of view of defensive fire power. On the whole, therefore, it is clear that Type 'C' has insufficient advantages over Type 'B' to compensate for the disadvantage of reduced numbers. The same may be said of Types 'D' and 'E', and it appears unnecessary to consider them any further.

90. To sum up, it is clear that the ideal bomber must be large enough to carry an economical load of bombs with an

operational radius of action of 750 miles, at a speed high enough to make interception by the contemporary fighters difficult. It must be large enough to provide good facilities for navigation, bomb-aiming, and W/T communication, and to possess a fire power sufficient to keep the fighter at a distance, and it must have the smallest possible number of blind spots. In order to obtain all these qualities we must have a bomber of about the size of Type 'B'. Any considerable increase beyond this size, although its characteristics as a bomber and its economy continue to improve up to and including Type 'D' and possibly Type 'E', introduces a counter-balancing factor in the form of a sharp reduction of the numbers that can be obtained for a given capital sum.

91. The conclusion therefore is that, at the present time, with the engines which are available and with our present knowledge of design and construction, the Type 'B' bomber offers the best compromise. Accordingly it is recommended that the type 'B' bomber should be selected for mass production as the standard equipment for the Bomber force at home and abroad.

92. It should be borne in mind, however, that the terms of reference for this paper limited our consideration to bombers intended for the Metropolitan Air Force, for which a range in still air of 2000 miles is sufficient. If it should be necessary, at a future date, to demand increased ranges, it would be necessary to increase the size, unless substantial reductions in speed and bomb load could be accepted. This paper has shown that the larger types of bomber possess certain marked advantages, and it is clear that, if the cost of them could be materially reduced, most of the disadvantages of adopting them would disappear. It is at least possible that the geodetic system of construction will enable this to be done, and for this reason, if for no other, the conclusions of this paper should be taken as affecting only the Metropolitan bomber of the immediate future.

Air Staff.
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March, 1938.

APPENDIX A.
SECRET

THE IDEAL BOMBER.
TABLE OF PERFORMANCES.

Col. No. 1.	2	3	4	5	6	7	8	9	10	11	12
	Range, 2000 miles.					Weights (lb)					
	Take off 700 yds. over 50 ft. screen in still air conditions.		Take off 1000 yds. over 50 ft. screen in still air condition.		Span			Cost per aeroplane including engine.	Number obtainable for £20,000,000	Total bomb lift of number of aircraft shown in column 10.	
TYPE.	Bombs. lb.	Cruising Speed. m.p.h.	Bombs. lb.	Cruising Speed. m.p.h.	feet	Gross with bomb load. lb. shown in Col. 2.	Tare.			With 700 yd take off tons.	With 1000 yd. take off tons.
A	1,000	265	See note below		58'-60'	18,000	9,000	£14,500	1380	616	616
B	2,500	270	8,000	266	80'-84'	35,000	18,950	£29,250	683	763	2434
C	4,000	275	12,000	270	96'-100'	55,000	27,000	£40,800	490	875	2625
D	8,000	280	20,000	275	122'-126'	80,000	44,700	£62,000	323	1153	2884
E	18,000	275	44,000	270	172'-180'	160,000	91,500	£120,500	166	1334	3260

NOTES. 1. In order to obtain the performance shown in Col. 3 it will be necessary to keep the body size so small that Type 'A' will have bomb cells for 1000 lb. only, but theoretically, for a take-off run of 1000 yds. with range 2000 miles it could carry 4,000 lb. bombs at a cruising speed of 262 m.p.h.

2. It is probable that the costs of the larger types will be lower than the figures shown in Col. 9, which are on the 'safe' side.

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APPENDIX B.

THE IDEAL BOMBER.

Flying Personnel

Table showing numbers required to man the number of I.E. aeroplanes which could be obtained for a capital expenditure of £20,000,000

Col. No. 1.	2	3	4	5	6	7	8	9	10	11
TYPE	CREW PER AEROPLANE					TOTAL FLYING PERSONNEL REQUIRED TO MAN THE NUMBER OF AEROPLANES WHICH COULD BE OBTAINED FOR A CAPITAL EXPENDITUR[E] OF £20,000,000.				
	Pilots	Air Observers	W/T Operator Air Gunners	Engineers	Total	Pilots	Air Observers	W/T Operator Air Gunners	Engineers	Tota[l]
A	2	1	1	–	4	2760	1380	1380	–	5520
B	2	1	2	–	5	1366	683	1366	–	3415
C	2	1	3	–	6	980	490	1470	–	2940
D	2	1	4	–	7	646	323	1292	–	2261
E	2	1	4	1	8	332	166	664	166	1328

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Appendix C.

The Ideal Bomber

Reinforcing Data

1.	2.	3.
	Reinforcing load with a range of 2750 miles.	
T Y P E.	Take off 700 yards over 50 ft. screen. Economical cruising speed 178 m.p.h. Disposable load in lbs.	Take off 1,000 yards over 50 ft. screen. Economical cruising speed 188 m.p.h. Disposable load in lbs.
A	-	2250
B	1650	6650
C	3200	10,000
D	6200	18,000
E	17,000	39,000

NOTE: The fuel required to attain a range of 2750 miles at most economical air speed would exceed that required for 2000 miles at maximum speed for economic cruising conditions by amounts varying between 107 glls. for Type 'A' to 135 glls. for Type 'E' but permanent wing takage for the 2750 miles range could be provided without detracting from operational performance.

R O Y A L A I R F O R C E.

ESTABLISHMENT OF A BOMBER SQUADRON 12 I.E. 2 ENGINED.

Policy:-

(1) PERSONNEL.

EXCLUDING FLYING CREWS.

Establishment No: Date: Authority:

TRADE GROUP	Annotations.	DETAIL.	OFFICERS. Air Marshals.	Air Vice Marshals.	Air Commodores.	Group Captains.	Wing Commanders.	Squadron Leaders.	Flight Lieutenants.	F/Lt's. or F/Officers	Flying Officers or Pilot Officers.	Non-serving Officers.	TOTAL.	AIRMEN AND CIVILIANS. Warrant Officers.	Flight Sergeants.	Sergeants.	Corporals.	Aircraftmen.	Civilian Staff.	TOTAL.	REMARKS.
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
		Headquarters.																			
		Adjutant.	-	-	-	-	-	-	1	-	-	-	1	-	-	-	-	-	-	-	
		Flying.	-	-	-	-	1	-	-	-	2	-	3	-	-	-	-	-	-	-	
V		Aircrafthands (General Duties)	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	3	-	5	
II		Armourers.	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	1	
II		Carpenters.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	
IV		Clerks (General Duties).	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	2	-	3	
I		Fitters I.	-	-	-	-	-	-	-	-	-	-	-	-	1	1	2	6	-	10	
I		Fitters (Armourer).	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	2	-	4	
I		Instrument Makers.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	1	
I		Instrument Repairers.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	
V		Mates.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6	-	6	
I		Metal Workers.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	
I		Wireless Operator Mechanics.	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	2	-	4	
		TOTAL HEADQUARTERS:	-	-	-	-	1	-	1	-	2	-	4	-	4	2	7	24	-	37	
		Two Flights.																			
		Flying.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
		Airmen Pilots.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
		Air Observers.																			
II		Armourers.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	2	
I		Fitters I.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	1	
I		Instrument Makers.	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-	-	2	
I		Wireless Operator Mechanics.	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	2	
II		Wireless Operators.	-	-	-	-	-	-	-	-	-	-	-	-	-	1	4	-	-	5	
I		Wireless Operator Mechanics.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	2	
II		Wireless Operators.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
V		Aircrafthands General Duties.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	10	-	12	
II		Armourers.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	10	-	12	
II		**Electricians.**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6	-	6	
IV		Equipment Assistants.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	2	
I		Fitters I.	-	-	-	-	-	-	-	-	-	-	-	-	2	4	11	-	-	17	
I		Fitters II.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	36	-	36	
II		Instrument Repairers.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	2	
V		Mates.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	12	-	12	
IV		Clerks G.D.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	2	
		TOTAL FLIGHTS:	-	-	-	-	-	-	-	-	-	-	-	-	2	8	23	82	-	115	
		TOTAL SQUADRON:	-	-	-	-	1	-	1	-	2	-	4	-	6	10	30	106	-	152	Type "A" 115 Sqns. " "B" 57 "

ROYAL AIR FORCE.

ESTABLISHMENT OF A BOMBER SQUADRON 4 ENGINED 12 I.E. Policy:

(1) PERSONNEL.

Establishment No: Date: EXCLUDING FLYING CREWS. Authority:

TRADE GROUP	Annotations.	DETAIL.	OFFICERS.											AIRMEN AND CIVILIANS.							REMARKS.
			Air Marshals.	Air Vice Marshals.	Air Commodores.	Group Captains.	Wing Commanders.	Squadron Leaders.	Flight Lieutenants.	F/Lt's.or F/Officers.	Flying Officers or Pilot Officers.	Non-serving Officers.	TOTAL.	Warrant Officers.	Flight Sergeants.	Sergeants.	Corporals.	Aircraftmen.	Civilian Staff.	TOTAL.	
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
		Headquarters.																			
		Adjutant.	-	-	-	-	-	-	1	-	-	-	1	-	-	-	-	-	-	-	
		Flying.	-	-	-	-	1	-	-	-	2	-	3	-	-	-	-	-	-	-	
V		Aircrafthands (General Duties)	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	3	-	5	
II		Armourers.	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	1	
II		Carpenters.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	
IV		Clerks (General Duties)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	2	-	3	
I		Fitters I.	-	-	-	-	-	-	-	-	-	-	-	-	1	1	2	9	-	13	
I		Fitters (Armourer).	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	2	-	4	
I		Instrument Makers.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	1	
II		Instrument Repairers.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	
V		Mates.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9	-	9	
I		Metal Workers.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	
I		Wireless Operator Mechanics.	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	3	-	5	
		TOTAL HEADQUARTERS:	-	-	-	-	1	-	1	-	2	-	4	-	4	2	7	31	-	44	
		Two Flights.																			
		Flying.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
		Airman Pilots.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
		Air Observers.																			
II		Armourers.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	2	
I		Fitters I.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	1	
I		Instrument Makers.	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-	-	2	
I		Wireless Operator Mechanics.	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	2	
II		Wireless Operators.	-	-	-	-	-	-	-	-	-	-	-	-	-	1	4	-	-	5	
I		Wireless Operator Mechanics.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	2	
II		Wireless Operators.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
V		Aircrafthands (General Duties)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	10	-	12	
II		Armourers.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	12	-	14	
II		Electricians.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6	-	6	
IV		Equipment Assistants.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	2	
I		Fitters I.	-	-	-	-	-	-	-	-	-	-	-	-	2	4	11	-	-	17	
I		Fitters II.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	48	-	48	
I		Instrument Repairers.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	2	
V		Mates.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	36	-	36	
IV		Clerks G.D.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	2	
		TOTAL FLIGHTS:	-	-	-	-	-	-	-	-	-	-	-	-	2	8	23	120	-	153	
		TOTAL SQUADRON:	-	-	-	-	1	-	1	-	2	-	4	-	6	10	30	151	-	197	Type "C" 41 Sqdns

29

ROYAL AIR FORCE.

ESTABLISHMENT OF A BOMBER SQUADRON 4 ENGINED 8 I.E.

Policy:-

(1) PERSONNEL.

Establishment No: Date: EXCLUDING FLYING CREWS. Authority:

TRADE GROUP	Annotations.	DETAIL.	OFFICERS: Air Marshals.	Air Vice Marshals.	Air Commodores.	Group Captains.	Wing Commanders.	Squadron Leaders.	Flight Lieutenants.	F/Lt's or F/Officers.	Flying Officers or Pilot Officers.	Non-serving Officers.	TOTAL.	AIRMEN AND CIVILIANS: Warrant Officers.	Flight Sergeants.	Sergeants.	Corporals.	Aircraftmen.	Civilian Staff.	TOTAL.	REMARKS.
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
		Headquarters.																			
		Adjutant.	-	-	-	-	-	-	1	-	-	-	1	-	-	-	-	-	-	-	
		Flying.	-	-	-	-	1	-	-	-	2	-	3	-	-	-	-	-	-	-	
		Aircrafthands (General Duties)	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	3	-	5	
		Armourers.	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	1	
		Carpenters.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	
		Clerks (General Duties)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	2	-	3	
		Fitters I.	-	-	-	-	-	-	-	-	-	-	-	-	1	1	2	6	-	10	
		Fitters (Armourer)	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	2	-	4	
		Instrument Makers	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	1	
		Instrument Repairers.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	
		Mates.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6	-	6	
		Metal Workers.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	
		Wireless Operators Mechanics.	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	3	-	5	
		TOTAL HEADQUARTERS:	-	-	-	-	1	-	1	-	2	-	4	-	4	2	7	25	-	38	
		Two Flights (excluding flying crews.)																			
		Aircrafthands (General Duties)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	6	-	8	
		Armourers.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	8	-	10	
		Electricians.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6	-	6	
		Equipment Assistants.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	2	
		Fitters I.	-	-	-	-	-	-	-	-	-	-	-	-	2	2	7	-	-	11	
		Fitters II.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	32	-	32	
		Instrument Repairers.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	2	
		Mates.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	24	-	24	
		Clerks (General Duties)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	2	
		Two Flights (less flying crews):	-	-	-	-	-	-	-	-	-	-	-	-	2	2	11	82	-	97	
		Total Squadron (less flying crews).	-	-	-	-	1	-	1	-	2	-	4	-	6	4	18	107	-	135	Type "D" - 40 Sqdns.

Type "B". APPENDIX "D".

30

ROYAL AIR FORCE.

ESTABLISHMENT OF A BOMBER SQUADRON 6 ENGINED 8 I.E. Policy:

(1) PERSONNEL.

Establishment No: Date: EXCLUDING FLYING CREWS. Authority:

TRADE GROUP	Annotations.	DETAIL.	OFFICERS											AIRMEN AND CIVILIANS							REMARKS.
			Air Marshals.	Air Vice Marshals.	Air Commodores.	Group Captains.	Wing Commanders.	Squadron Leaders.	Flight Lieutenants.	F/Lt's. or F/Officers	Flying Officers or Pilot Officers.	Non-serving Officers.	TOTAL.	Warrant Officers.	Flight Sergeants.	Sergeants.	Corporals.	Aircraftmen.	Civilian Staff.	TOTAL.	
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
		Headquarters.																			
		Adjutant.	-	-	-	-	-	-	1	-	-	-	1	-	-	-	-	-	-	-	
		Flying.	-	-	-	-	1	-	-	-	2	-	3	-	-	-	-	-	-	-	
V		Aircrafthands (General Duties)	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	3	-	5	
II		Armourers.	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	1	
II		Carpenters.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	
IV		Clerks (General Duties)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	2	-	3	
I		Fitters I.	-	-	-	-	-	-	-	-	-	-	-	-	1	1	2	9	-	13	
I		Fitters (Armourer)	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	4	-	6	
I		Instrument Makers.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	1	
II		Instrument Repairers.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	
V		Mates.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9	-	9	
I		Metal Workers.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	
I		Wireless Operator Mechanics.	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	4	-	6	
		TOTAL HEADQUARTERS:	-	-	-	-	1	-	1	-	2	-	4	-	4	2	7	34	-	47	
		Two Flights.																			
		Flying.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
		Airman Pilots.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
		Air Observers.																			
II		Armourers.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	1	
I		Fitters I.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	1	
I		Instrument Makers.	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	1	
I		Wireless Operator Mechanics.	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	2	
II		Wireless Operators.	-	-	-	-	-	-	-	-	-	-	-	-	-	1	2	-	-	3	
I		Wireless Operator Mechanics.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	2	
II		Wireless Operators.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
V		Aircrafthands (General Duties)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	6	-	8	
II		Armourers.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	16	-	18	
II		Electricians.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6	-	6	
IV		Equipment Assistants.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	2	
I		Fitters I.	-	-	-	-	-	-	-	-	-	-	-	-	2	4	8	-	-	14	
I		Fitters II.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	48	-	48	
II		Instrument Repairers.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	2	
V		Mates.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	48	-	48	
IV		Clerks G.D.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	2	
		TOTAL FLIGHTS.	-	-	-	-	-	-	-	-	-	-	-	-	2	8	16	132	-	158	Type "E" - 21 Sqdns.
		TOTAL SQUADRON:	-	-	-	-	1	-	1	-	2	-	4	-	6	10	23	153	-	205	

Type "E". APPENDIX "D".

31 Ex?

ROYAL AIR FORCE.

ESTABLISHMENT OF A BOMBER SQUADRON 6 ENGINED 8 I.E. Policy:

(1) PERSONNEL.

Establishment No: Date: EXCLUDING FLYING CREWS. Authority:

TRADE GROUP	Annotations.	DETAIL.	OFFICERS											AIRMEN AND CIVILIANS							REMARKS.
			Air Marshals.	Air Vice Marshals.	Air Commodores.	Group Captains.	Wing Commanders.	Squadron Leaders.	Flight Lieutenants.	F/Lt's. or F/Officers	Flying Officers or Pilot Officers.	Non-serving Officers.	TOTAL.	Warrant Officers.	Flight Sergeants.	Sergeants.	Corporals.	Aircraftmen.	Civilian Staff.	TOTAL.	
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
		Headquarters.																			
		Adjutant.	-	-	-	-	-	-	1	-	-	-	1	-	-	-	-	-	-	-	
		Flying.	-	-	-	-	1	-	-	-	2	-	3	-	-	-	-	-	-	-	
V		Aircrafthands (General Duties)	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	3	-	5	
II		Armourers.	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	1	
II		Carpenters.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	
IV		Clerks (General Duties)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	2	-	3	
I		Fitters I.	-	-	-	-	-	-	-	-	-	-	-	-	1	1	2	9	-	13	
I		Fitters (Armourer)	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	4	-	6	
I		Instrument Makers.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	1	
II		Instrument Repairers.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	
V		Mates.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9	-	9	
I		Metal Workers.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	
I		Wireless Operator Mechanics.	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	4	-	6	
		TOTAL HEADQUARTERS:	-	-	-	-	1	-	1	-	2	-	4	-	4	2	7	34	-	47	
		Two Flights.																			
		Flying.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
		Airman Pilots.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
		Air Observers.																			
II		Armourers.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	1	
I		Fitters I.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	1	
I		Instrument Makers.	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	1	
I		Wireless Operator Mechanics.	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	2	
II		Wireless Operators.	-	-	-	-	-	-	-	-	-	-	-	-	-	1	2	-	-	3	
I		Wireless Operator Mechanics.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	2	
II		Wireless Operators.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
V		Aircrafthands													-	-	2	6	-	8	
		(General Duties)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	16	-	18	
II		Armourers.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6	-	6	
II		Electricians.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
IV		Equipment												-	-	-	-	2	-	2	
		Assistants.	-	-	-	-	-	-	-	-	-	-	-	-	2	4	8	-	-	14	
I		Fitters I.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	48	-	48	
I		Fitters II.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
II		Instrument	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	2	
		Repairers.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	48	-	48	
V		Mates.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	2	
IV		Clerks G.D.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
		TOTAL FLIGHTS.	-	-	-	-	-	-	-	-	-	-	-	-	2	8	16	132	-	158	Type "E" - 21 Sqdns.
		TOTAL SQUADRON:	-	-	-	-	1	-	1	-	2	-	4	-	6	10	23	166	-	205	